
AMS-02 - ACOP Critical Design Review

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EXPRESS Integration Agreement (EIA) Info - 1

- There is not yet a baseline for the ACOP EIA. The following relates some of the information what will be contained in the EIA.
- ACOP is a portion of the AMS-02 payload. It will reside within the US-Lab pressurized volume of ISS and provide support to the AMS-02 attached payload portion.
- AMS-02 is developed under “SSP 57113 Payload Integration Agreement for Alpha Magnetic Spectrometer-02 (AMS-02)” (Note: This PIA also not yet baselined). In the event of inconsistency between the ACOP EIA and the AMS-02 PIA, the PIA will be considered authoritative.
- The primary purposes of ACOP are to provide a large memory space to record AMS Experiment data and to provide a crew monitoring and control mechanism for the attached site payload.
- ACOP Mission duration is about 4 Years; it will cover the AMS-02 Mission and it will operate with AMS-02 (3+ years operating).

EIA Info - 2

- ACOP will be accommodated in a MDL/ISS locker inside a Standard 8/2 Express Rack
- ACOP is to be delivered and checked out 3 to 6 Months before the arrival of the external AMS-02 un-pressurized payload.
- The ACOP on orbit transportation baseline is by MPLM transportation rack. It can also be accommodated in the shuttle MDL.
- ACOP is categorized as a “Standard Express Rack payload” with the following deviations:
 - HRDL communication lines (Standard ER should exploit standard ER I/F’s only)
 - ORU parts soft bag stowage container (Standard ER should not have stowage items external to the payload)

EIA Resources Requirements

- Utilize one (1) International Standard Payload Rack (ISPR) ISS/MDL locker for the planned 4-years of payload mission life. (OZ3 engineering study identified ER4 in P2 as continuous powered.)
- ACOP will utilize 1 soft bag MDL equivalent for ORU part transportation and stowage for recording media (removable hard drives) and spare parts.
- Utilize the Express Rack Payload Computer to provide a man machine interface to the Crew.
- Earlier ISS flight (AMS-02 L-3 to L-6 months) required to stage/install the ACOP assembly in ISS locker and install/initialize/checkout in the pressurized volume before AMS-02 truss-attached payload assembly portion is integrated and berthed on station.

HRDL Requirements

- HRDL connections are a special resource required for ACOP that usually are not available for a standard Express Rack payload.
- Full time – (1) TX and (1) RX fiber are used for a AMS-02 to ACOP private payload network to support the complex data management required.
- Intermittent – (1) TX fiber is used to downlink AMS-02 telemetry data.
- OZ3 engineering study identified (2) TX and (1) RX HRDL fibers on the UIP as available during the AMS-02 mission. (TX and RX under TESS (complete mission) and TX under MELFI(as initiation location, may have to move)).
- To connect the HRDL channels, optical fiber cables will be installed inside the laboratory from ACOP to these J7 connectors, following a defined path agreed between EPIM and AMS-02 Program.

EIA Resources Table

NOTE: The values found in Table 8.1-1 are controlled by SSP 57113 Payload Integration Agreement for Alpha Magnetic Spectrometer-02 (AMS-02). In event of conflict SSP 57113 is the controlling document.

Table 8.1-1 ESTIMATED Steady State Payload Resource Requirements

| <u>Resources</u> | <u>Resource Requirements</u> |
|---|--|
| On-Orbit Volume (cubic meters) | 0.5 (2 MDL equivalents) (TBR) |
| Up Mass (kilograms per year) | 46 installation plus 75/yr (TBR) |
| Down Mass (kilograms per year) | 23 de-installation plus 75/yr (TBR) |
| Up Volume (cubic meters per year) | 0.5 installation plus .75/yr (TBR) |
| Down Volume (cubic meters per year) | .25 de-installation plus .75/yr (TBR) |
| Energy (kilowatt hours per year) | 1728 (TBR) |
| Crew Time (hours per year) | 6hr (TBR) |
| Communications Downlink (terabits per year) | 70 (TBR) |
| Communications Uplink (terabits per year) | 8E-6 (TBR) |
| Late/Early Access (launch/return/both/none) | N/A |
| Support Equipment (list) | N/A |
| Other Coordinated Payloads (payload name) | AMS-02 |
| Additional Requirements (specify): | 2 HRDL TX and 1 HRDL RX connections. 1 TX and 1 RX APS connections continuous. Continuous power. |

EIA interface requirements

- The following I/F's are required in the EIA
- Interfaces Required (Yes/No)
 - Power
 - 200 W (24Hours x 7 Days) YES
 - Data
 - RS 422 YES
 - Ethernet YES
 - PD Developed Software on ERLaptop Computer YES
 - 5 Vdc discrete NO
 - 2 TX HRDL and 1 RX HRDL (Not ER Standard I/F) YES
 - Cooling
 - EXPRESS Rack Avionics Air Assembly (AAA) Air Sys YES

Interface Control Documents Applicable 1/2

- The applicable ICDs are:
 - SSP52000-IDD-ERP for
 - Physical & Mechanical I/F's
 - Structural I/F's
 - Thermal I/F's
 - Power I/F's
 - Electrical I/F's
 - Control Data I/F's
 - Software I/F's
 - Human Factor I/F's
 - Safety

Interface Control Documents Applicable 2/2

- SSP 50183 Physical Media, Physical Signalling & link-level Protocol Specification for ensuring Interoperability of High Rate Data Link Stations on the International Space Program
- SSP 52050 S/W Interface Control Document for ISPR (HRDL section only)
- This last two documents are inserted in order to cover non-standard HRDL interfaces.

Physical & Mechanical I/F's requirements

- The Physical & Mechanical I/F's will be compliant to the SSP52000-IDD-ERP section 3.3 concerning the standard modular MDL/ISS locker sections. Deviations from the standards are:
 - The front panel configuration. A custom front panel will be manufactured.
- The Mass Budget estimated value is about 26Kg (for ACOP only, ORU parts (1 MDL) excluded).

Operations Scenario

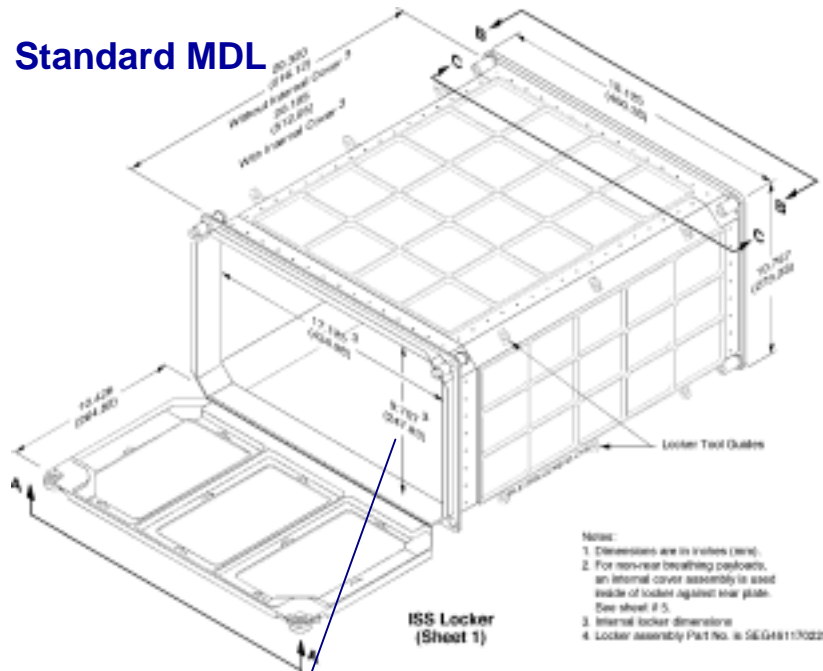
- ACOP is principally a ground operated payload.
- ACOP is powered and active whenever AMS-02 is active. Only short (<8hr outages).
- ACOP maintains an active bi-directional connection via the HRDL interface to AMS-02 at all times.
- The AMS-02 TX connection for this full time link may be tee'd by the APS to the HRFM/KU for downlink.
- Nominally AMS-02 payload operations needs to see 2Mbit/sec of data near real time (KU- band link).
- ACOP provides the mechanism for the crew to monitor and control AMS-02. Both front panel and PCS based interfaces supported.
- As KU access is available, ACOP will be commanded to use its' additional TX connection to down link data. ACOP will have the ability to burst this transmission (~20Mbits/sec).

Operations - Recording Management

- All data transmitted by AMS-02 is recorded onto ACOP's hard drives as a master copy of the AMS-02 science data.
- When ACOP has acknowledged that the data is recorded, AMS-02 can release that data from its buffers.
- The four hard drives installed in ACOP provide an estimated 30 days of recording (Note: Dependent on event rate and size. Based on 200GB drives. Hopefully this will grow substantially.)
- The four installed hard drives will require periodic replacement by the ISS crew from the onboard stock of empty drives. (30 minute operation about every 30 days.)
- A batch of 20 hard drives provides 150 days of recording capacity.
- New batches of hard drives will be delivered by STS and the original master copies of the AMS-02 data will be returned to earth by STS.

Mechanical Design (MDL)

Standard MDL



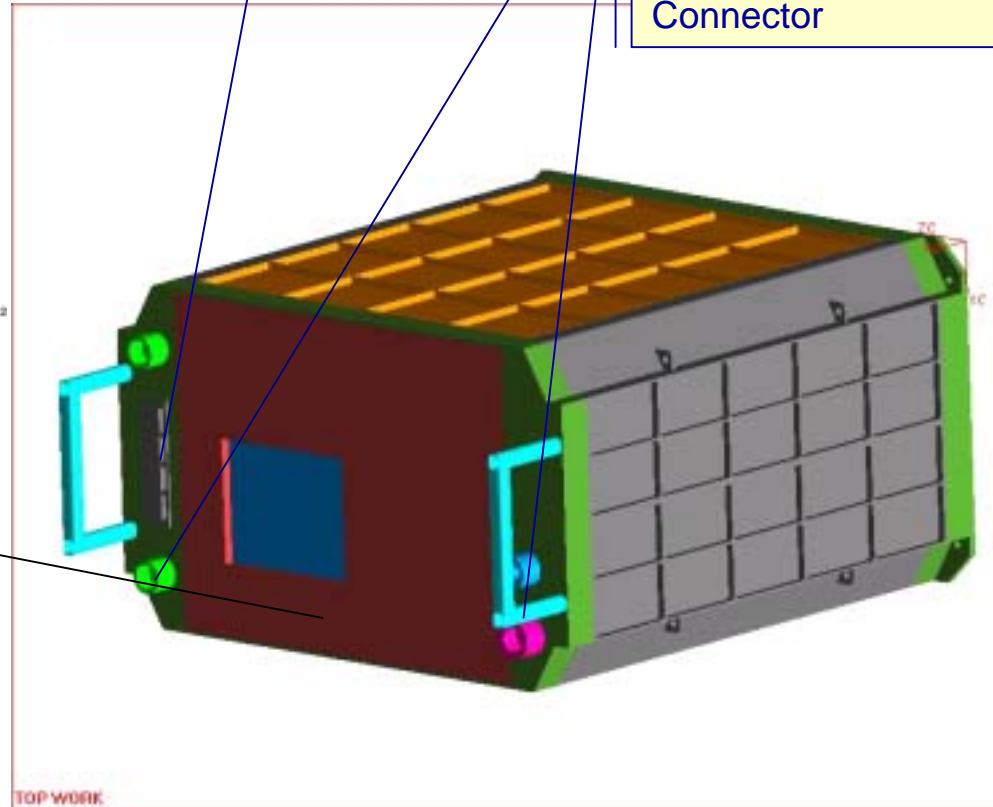
ISS Locker
(Sheet 1)

ISS Locker Size

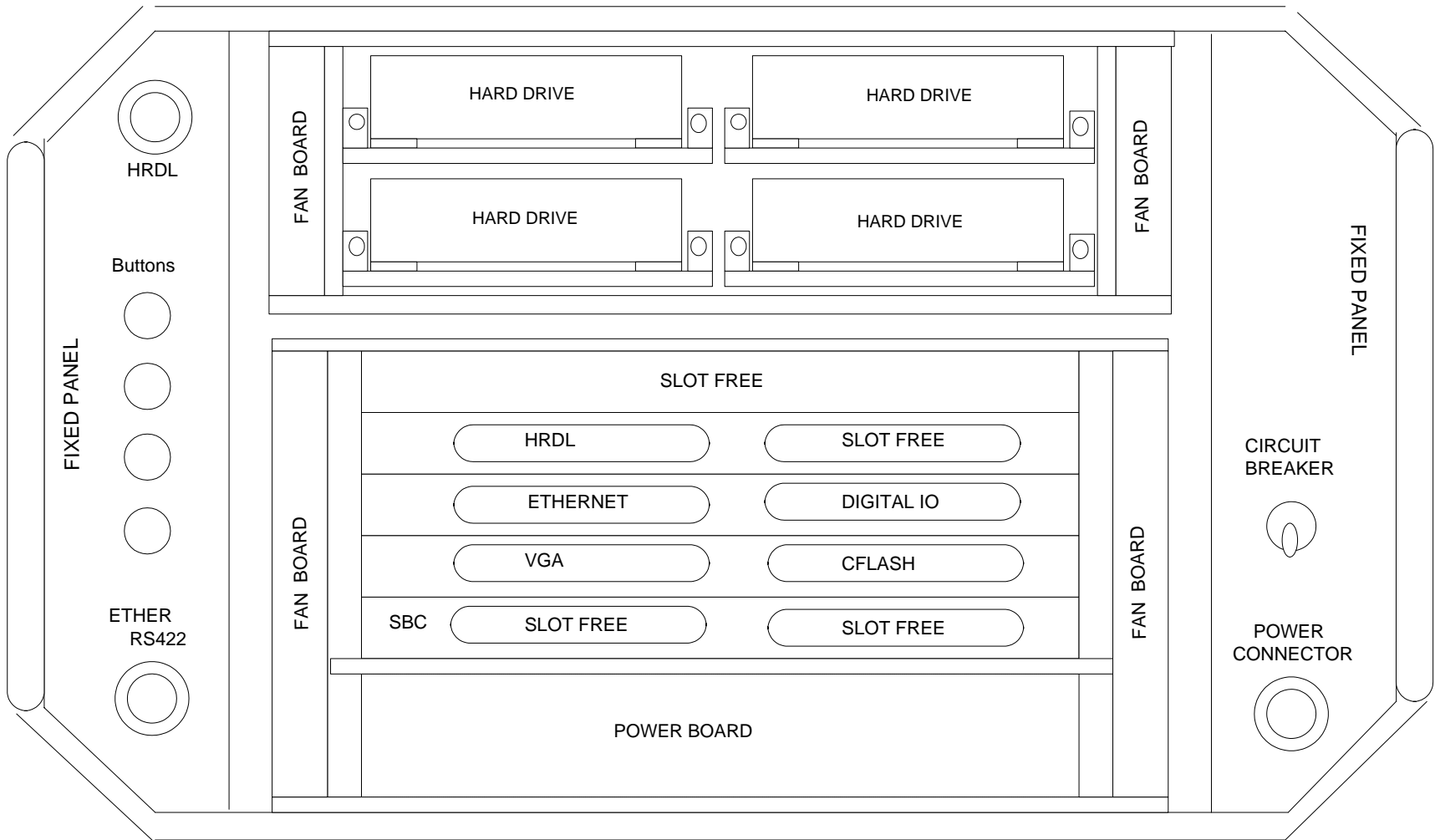
- Width 434,98mm
- Height 264,82mm
- Length 516,12mm

Front panel buttons

POWER(28v) and
DATA (HRDL
(2tx,1rx), 1 Rs422,
2 Ethernet)
Connector



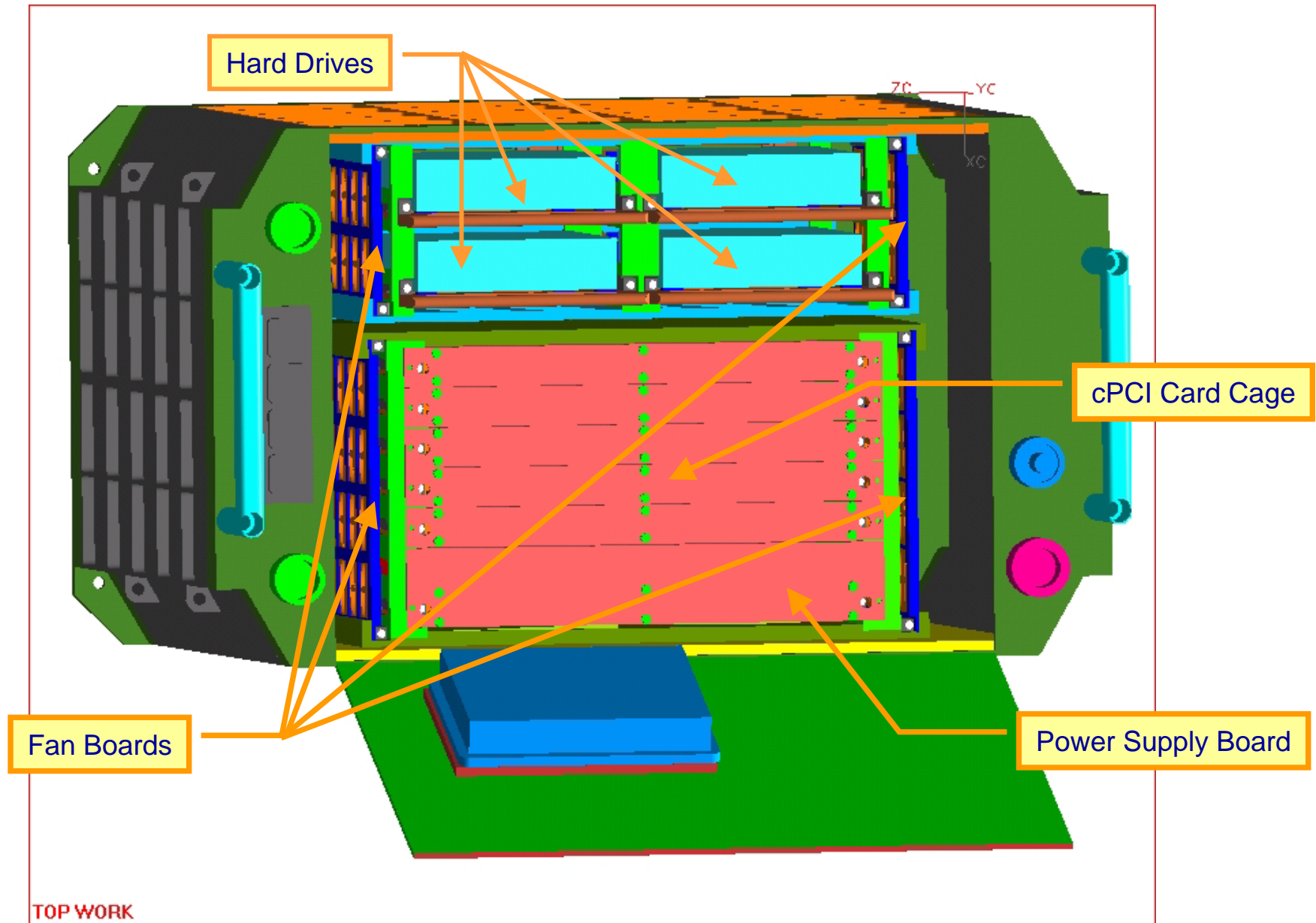
Mechanical Design: FM Front View



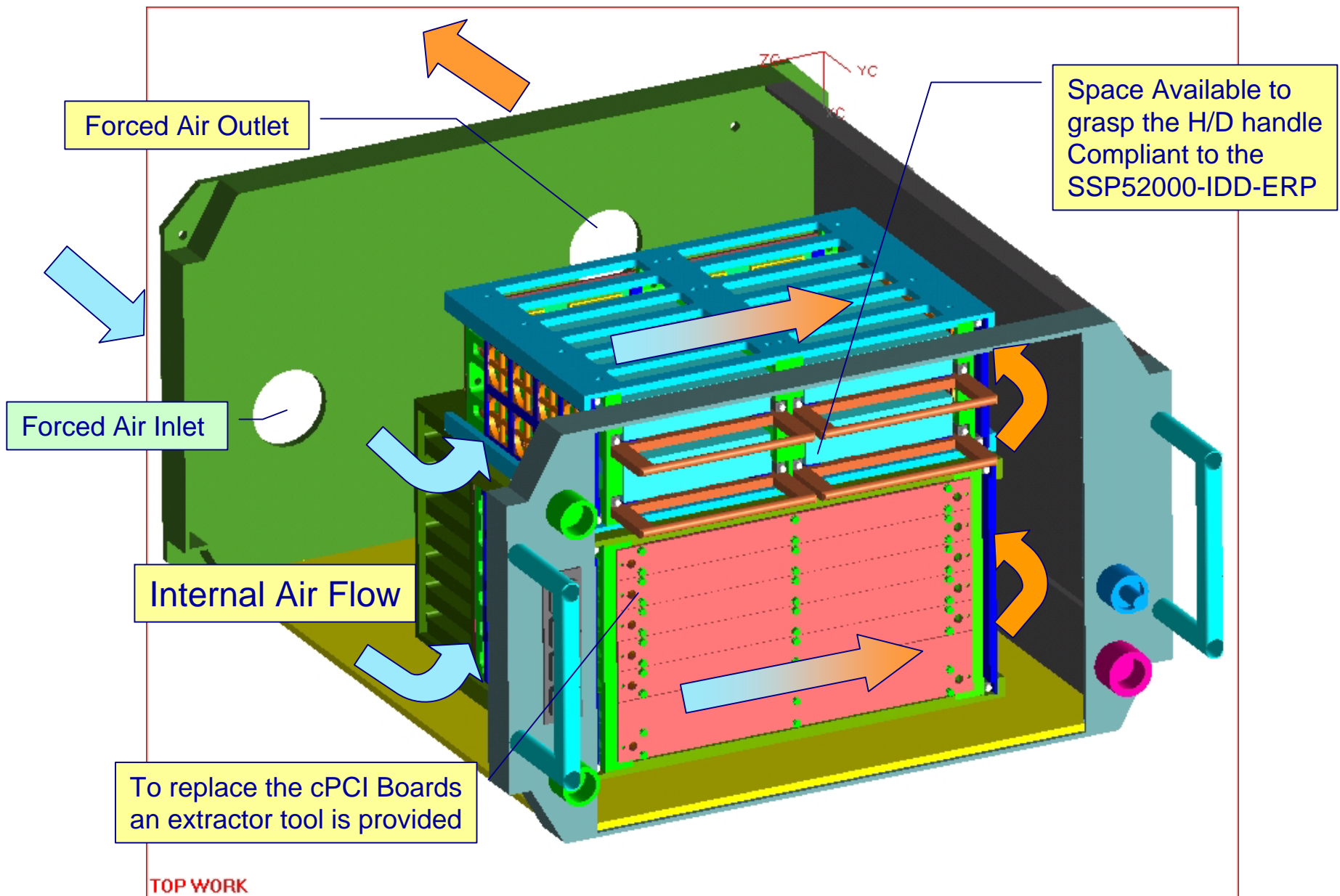
FRONT PANEL OPENED

All the Boards are replaceable

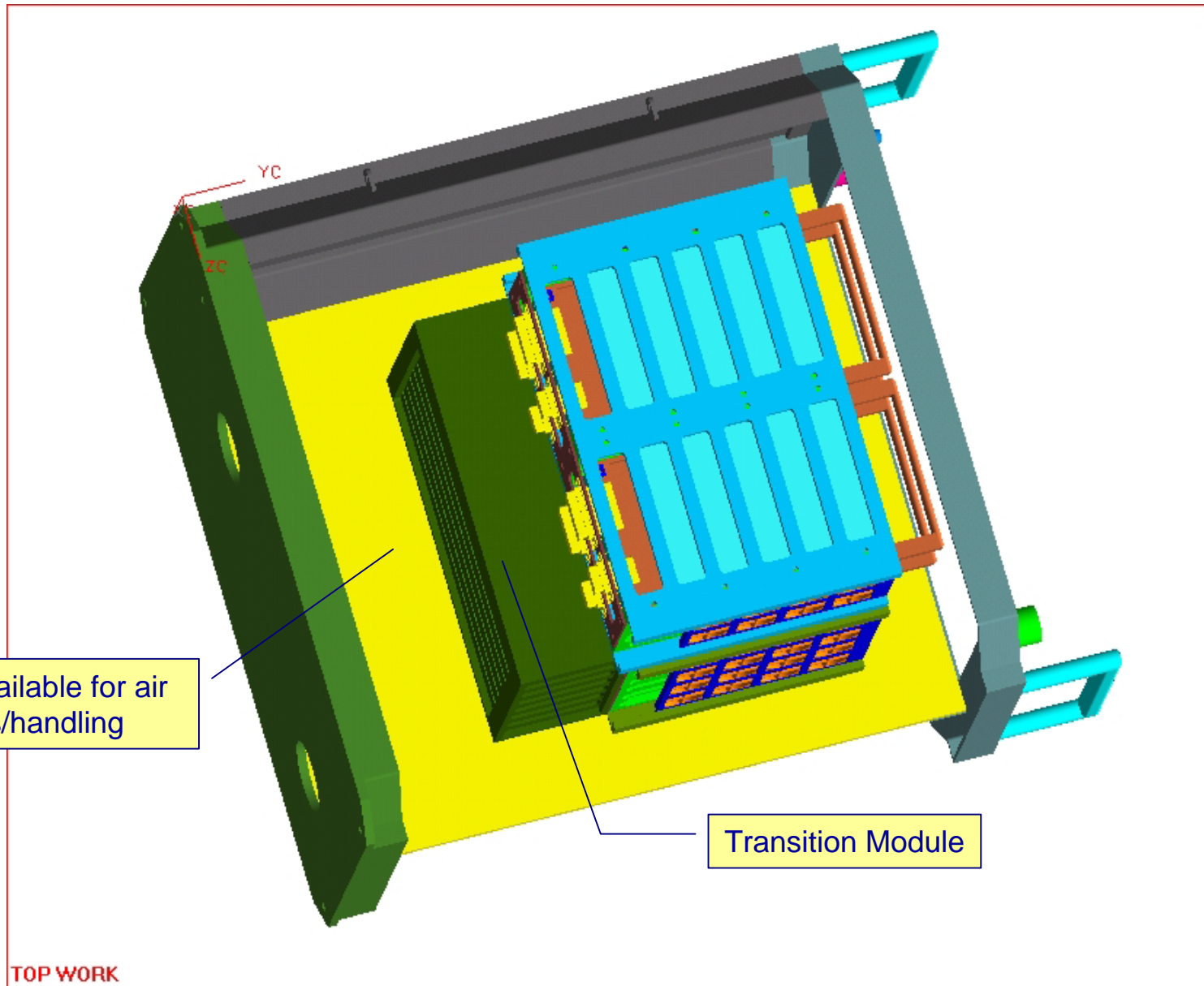
Mechanical Design



Mechanical Design – Air Flow



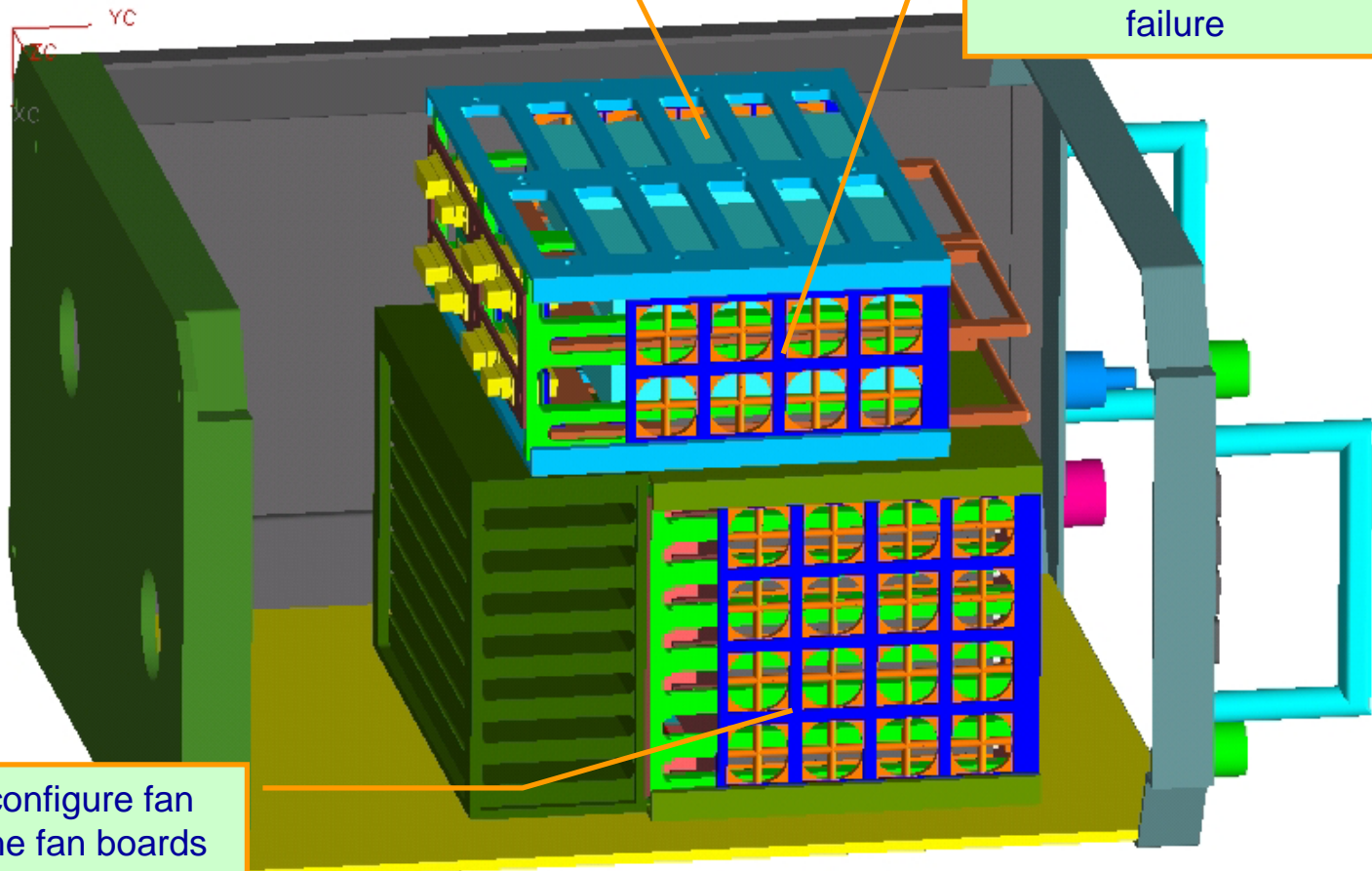
Mechanical Design – Transition Module



Mechanical Design – Fan Boards

The H/D's and Boards racks structure is open in order to maximize the air flow

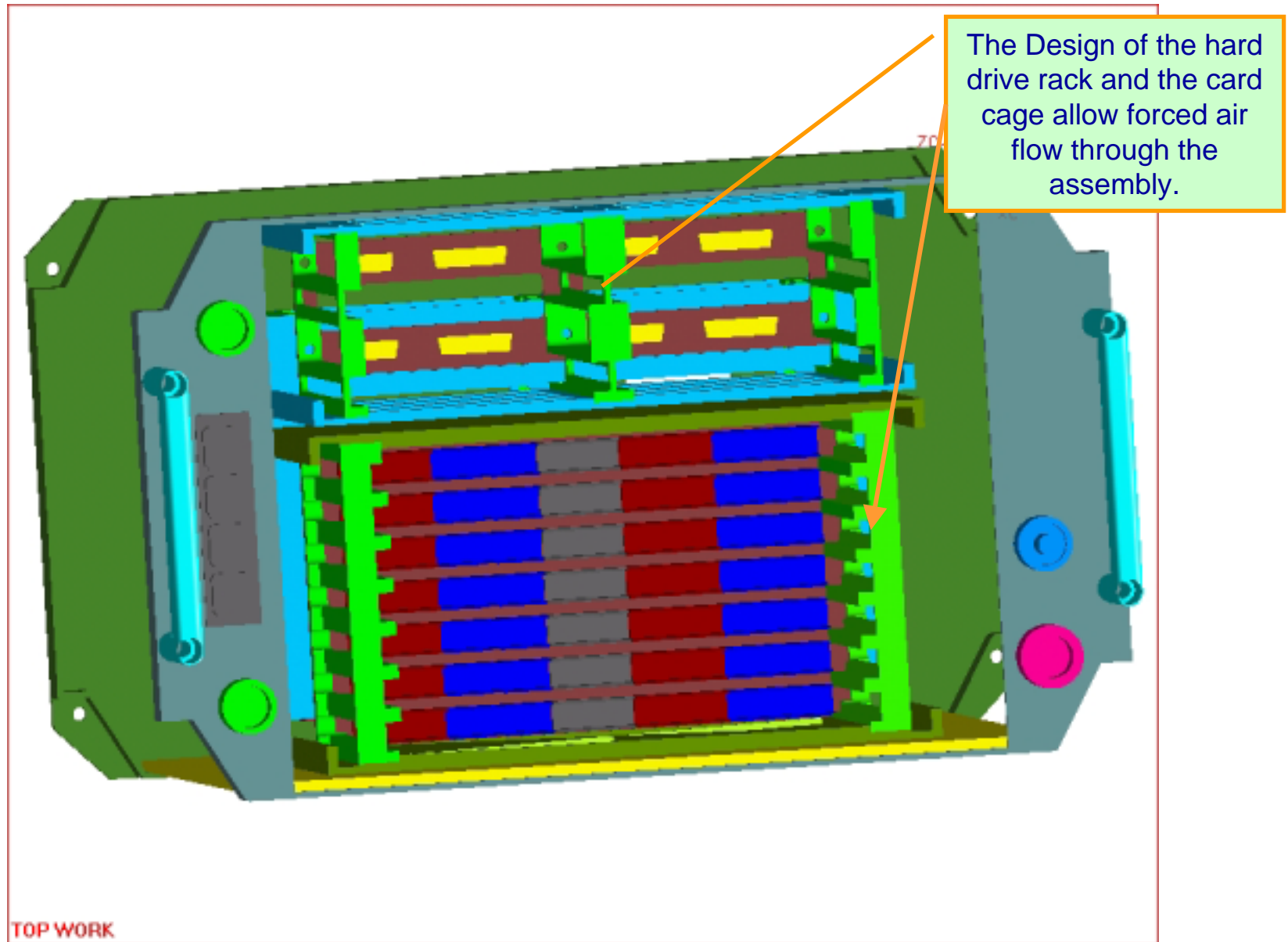
The Design of the fan boards allows redundancy in case of failure



Flexibility to configure fan locations on the fan boards to optimize cooling

TOP WORK

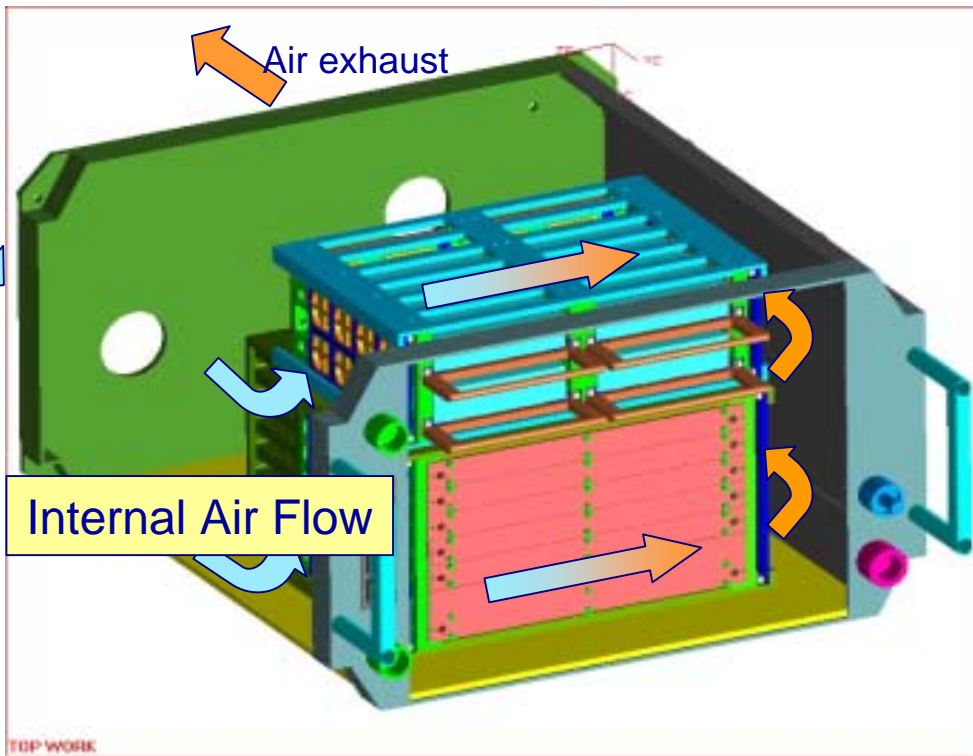
Mechanical Design



Thermal Cooling requirements

- Thermal Cooling design will be compliant to the SSP52000-IDD-ERP document section 5
- Ducted Air and Cooling via Avionics Air Assembly ($\leq 200\text{Watt}$) will be required for ACOP.
- ACOP will provide for internal air circulation 12 fans CFM (TBD). Fans redundancy will be provided. Noise control is provided by fan speed controls.
- The Front Panel surface temperature which is exposed to the Crew Members bare skin contact shall be maintained between -18°C and 49°C (as define in the IDD document)

Thermal Cooling Design



Thermal Analysis will be provided

The H/D's and Boards racks structure is opened in order to allow and maximize the air flow

The fan board will allow to accommodate different dimension fans. Up to 2 or 8 fans in the HD fan board and 16 or 4 fans in the Rack fan board

The Design of the fan boards allow the fan redundancy in case of failure

Flexibility to configure the fan positioning in the fan boards structure

Mass Budget

| ACOP FLIGHT MODEL: MASS BUDGET | | | | |
|----------------------------------|------------------|--------------------------|--------------|------|
| Description | Manufacturer | Part Number | (g) | unit |
| Electronics | | | | |
| CompactPCI Single Board Computer | SBS Technologies | CK365C (PPC750 256MByte) | 492 | 1 |
| Transition Board | SBS Technologies | CK3-TM | 250 | 1 |
| Transition Board | CGS | | 200 | 2 |
| PMC 3101-FP Network interface | SBS Technologies | PMC-3101-FP | 90 | 1 |
| PMC Digital I/O | SBS Technologies | TPMC-680 | 74 | 1 |
| PMC Video | SBS Technologies | PMC-VIDEO PLUS | 58 | 1 |
| CompactPCI 6U PMC Carrier board | SBS Technologies | CP-620 | 310 | 3 |
| PMC - Compact FLASH carrier w/ID | BMV Ltd | PMC-CF2 | 200 | 1 |
| PMC ACOP 6T | MIT | ACOP 6T | 300 | 1 |
| Prototyping boards | CGS | | 300 | 1 |
| cPCI PCB | CGS | | 800 | 1 |
| LCD Monitor | TBD | | 600 | 1 |
| 2Fan board | CGS | | 800 | 2 |
| 3Fan board | CGS | | 1000 | 2 |
| Power Distribution | CGS | | 1500 | 1 |
| Hard Drives | | | | |
| IDE Drives | Maxtor | ATA/133 120GB | 800 | 4 |
| Connectors Cable | | | | |
| Connectors, Cable | | | 2000 | 1 |
| Mechanical Infrastructure | | | | |
| Electronics Box | CGS | | 12000 | 1 |
| Hard Drives Chassis | CGS | | | |
| ISS Locker | TBD | | | |
| Front Panel | CGS | | | |
| ACOP FLIGHT MASS | | | 25796 | |
| ORU Parts | | | | |
| Hard Drives | | | 630 | 20 |
| Data Handling Boards | | | 1000 | 5 |
| Power Board | | | 1500 | 1 |
| 2 Fans boards | | | 800 | 2 |
| 3 Fans boards | | | 1000 | 2 |
| ORU PARTS MASS | | | 22700 | |

Power/Electrical I/F's requirements

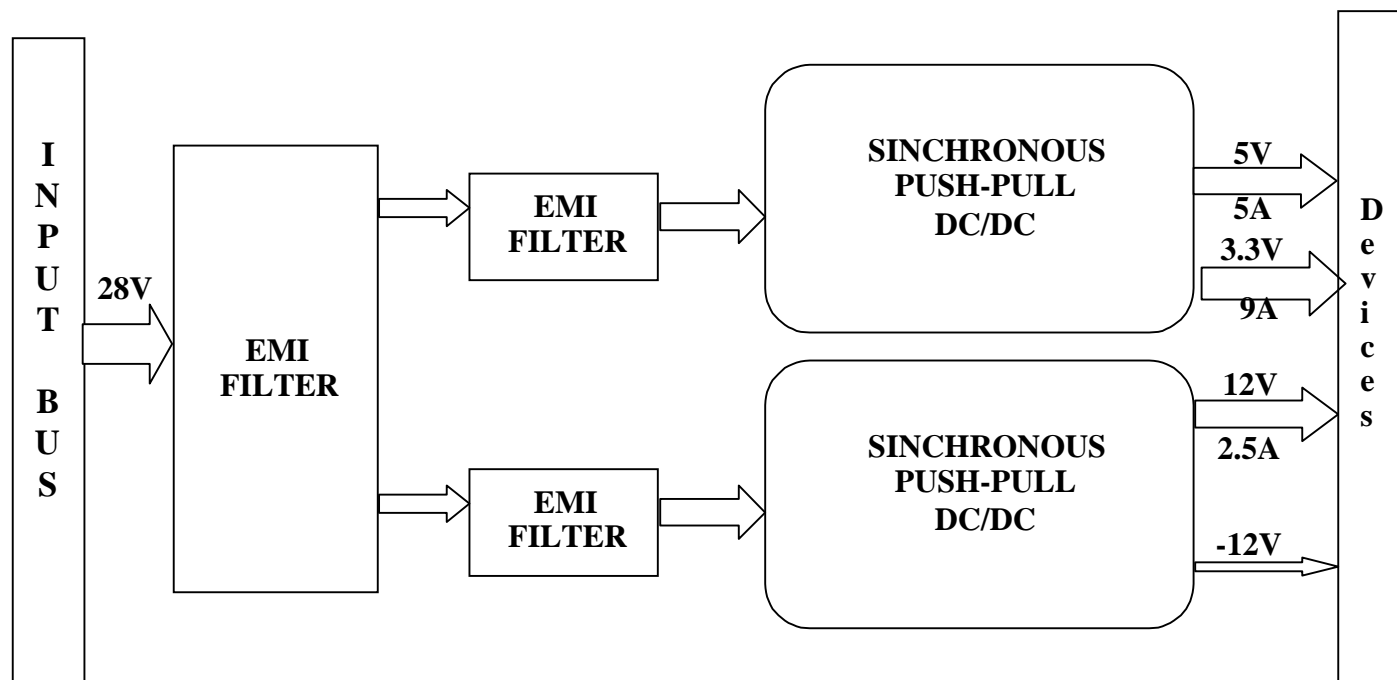
- The Power requirement will be compliant to the SSP52000-IDD-ERP document section 6
- ACOP will not be powered during STS transportation.
- On ISS ACOP will be powered from the ER upper or lower connector panel. A cable, with connectors meeting SSP-52000-IDD-ERP section 6.6, will be provided to link ACOP's front panel power connector to the ER connector panel.
- ACOP will provide overload protection devices (fuses and circuit breaker) for the power input line.
- ACOP power request is $\leq 200\text{Watt}$ (TBC). At present the Estimated value (with 30% of margin) is about 110W average.
- ACOP input power line will be isolated from the structure by at least 1 Mega Ohm with a parallel capacitance of $\leq 10\text{MicroF}$ measured at ACOP interface connector contact

Power Budget

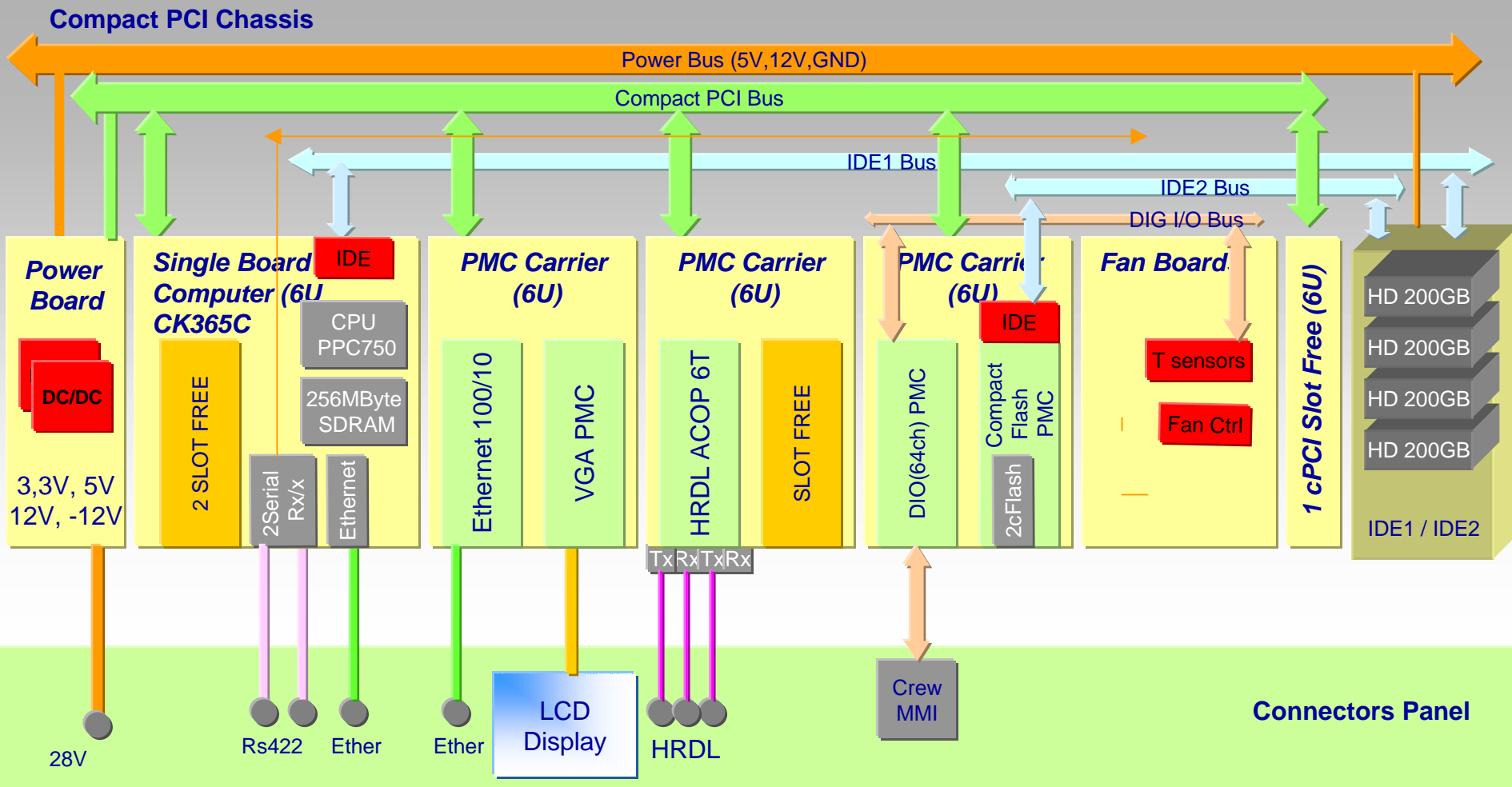
| ACOP FLIGHT MODEL: Power Budget | | | | | | | | | | |
|---------------------------------|-----------------------------------|------------------|--------------------------|--------------------------|------|------|-------|-------|--------------|--|
| | | | | | | | | | | |
| | Description | Manufacturer | Part Number | Current for each outlets | | | | Units | Power (Watt) | |
| | | | | V | V | V | V | | | |
| | | | | 3.3 | 5.0 | 12.0 | -12.0 | | | |
| | | | | mA | mA | mA | mA | | | |
| Boards | | | | | | | | | | |
| | CompactPCI Single Board Compute | SBS Technologies | CK365C (PPC750 256MByte) | 5160 | 200 | 0 | 0 | 1 | 18 | |
| | Transition Board | SBS Technologies | CK3-TM | 0 | 0 | 0 | 0 | 1 | 0 | |
| | Transition Board | CGS | | 0 | 0 | 0 | 0 | 2 | 0 | |
| | 2 Fan board | CGS | | 0 | 180 | 0 | 0 | 2 | 2 | |
| | 3 Fan board | CGS | | 0 | 270 | 0 | 0 | 2 | 3 | |
| | Prototype board??? | CGS | | 0 | 100 | 100 | 0 | 1 | 2 | |
| | CompactPCI 6U PMC Carrier board | SBS Technologies | CP-620 | 90 | 0 | 0 | 0 | 3 | 1 | |
| | cPCI bus | CGS | | 0 | 0 | 0 | 0 | 1 | 0 | |
| PMC | | | | | | | | | | |
| | PMC 3101-FP Network interface | SBS Technologies | PMC-3101-FP | 500 | 50 | 0 | 0 | 1 | 2 | |
| | PMC Digital I/O | SBS Technologies | TPMC-680 | 100 | 70 | 0 | 0 | 1 | 1 | |
| | PMC Video | SBS Technologies | PMC-VIDEO PLUS | 0 | 110 | 0 | 0 | 1 | 1 | |
| | PMC - Compact FLASH carrier w/IDE | BMV Ltd | PMC-CF2 | 300 | 200 | 0 | 0 | 1 | 2 | |
| | PMC ACOP 6T | MIT | ACOP 6T | 300 | 300 | 0 | 0 | 1 | 2 | |
| Hard Drives | | | | | | | | | | |
| | IDE Drives | Maxtor | ATA/133 120GB | | | | | 4 | | |
| | Seek(mA) | | | 0 | 858 | 662 | 0 | 1 | 12 | |
| | Idle(mA) | | | 0 | 668 | 334 | 0 | 1 | 7 | |
| | Standby(mA) | | | 0 | 90 | 37 | 0 | 2 | 2 | |
| LCD Monitor | | | | | | | | | | |
| | TBD | | | 0 | 0 | 650 | 0 | 1 | 8 | |
| Total Current | | | | 6630 | 3636 | 1820 | 0 | | | |
| Total Current with | | | | 8619 | 4727 | 2366 | 0 | | | |
| 30% of Margin | | | | | | | | | | |
| Power Outlets 3.3V | | | | | | | | | 28 | |
| Power Outlets 5V | | | | | | | | | 24 | |
| Power Outlets 12V | | | | | | | | | 28 | |
| Power Outles -12V | | | | | | | | | 0 | |
| Total Power | | | | | | | | | 80 | |
| Power Distribution board | | | | | | | | | | |
| | ACOP PDB (75% efficiency) | CGS | | | | | | | 27 | |
| Total Power (Input) | | | | | | | | | 107 | |

Power Board Schematic

| | |
|-------------------|----------|
| Power Outlet 3.3V | 28 Watt |
| Power Outlet 5V | 24 Watt |
| Power Outlet 12V | 28 Watt |
| Power Outlet -12V | optional |



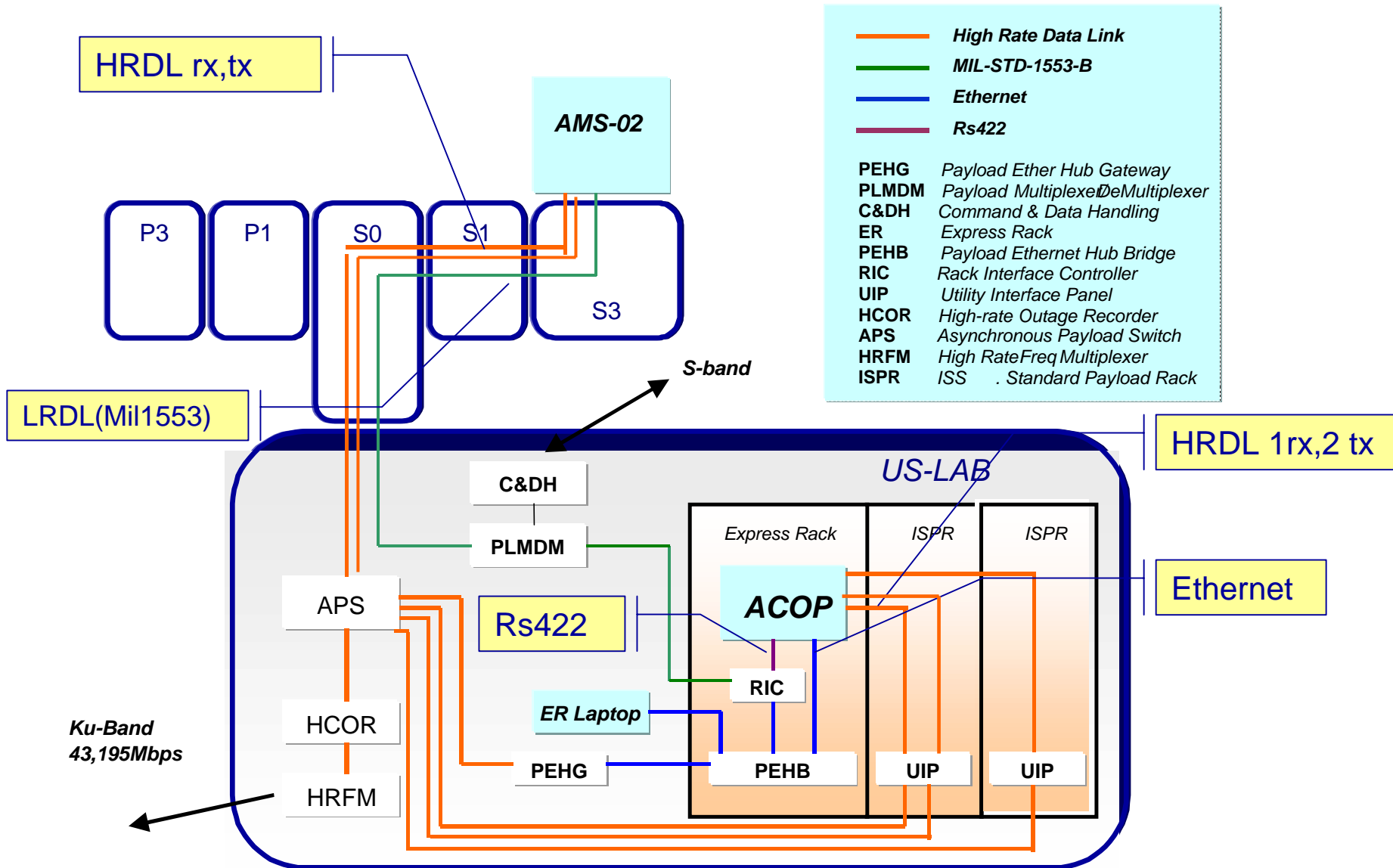
ACOP electrical architecture



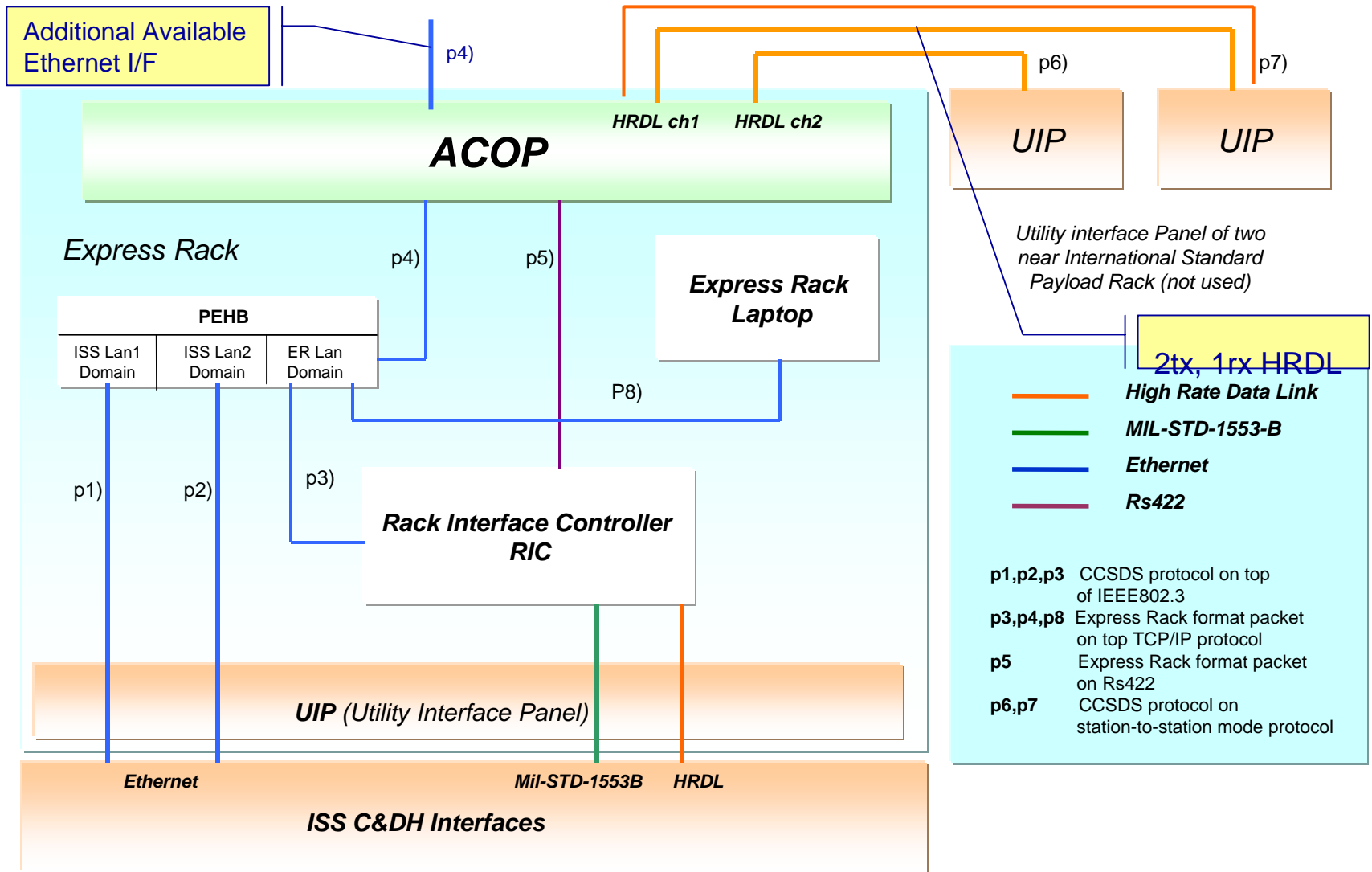
Command & Data Interface requirements

- The following Data Interface requirements will meet the SSP52000-IDD-ERP document section 9.
 - Ethernet Interface. It will provide ER protocol to communicate to the RIC
 - Rs422 Interface.
- The HRDL Interface will meet the SSP52050 and SSP50183 documents.

Command & data Handling: ISS Data I/F



Command & data Handling: ER Data I/F



Command & data Handling: RIC Data I/F

- RIC available data packets on Ethernet I/F. In the utilization column is defined the packets utilization in case of ACOP. The table is extracted from SSP52000-IDD-ERP

| Description | Source | Destination | Frequency | Data Format | Utilization |
|---------------------------------------|---------------|--------------------|-------------------|--------------------|--------------------|
| <u>Ethernet Payload to RIC</u> | | | | | |
| Payload Health and Status | Payload | RIC | 1Hz | Ethernet | Yes |
| PEP Bundle request | Payload | RIC | Async | Ethernet | No |
| PEP Procedure Execution Request | Payload | RIC | Async | Ethernet | No |
| Rack Time Request | Payload | RIC | Async | Ethernet | Yes |
| Ancillary Data Config Control | Payload | RIC | Async | Ethernet | No |
| Payload Telemetry Downlink Data | Payload | RIC | Async | Ethernet | No |
| EMU File Transfer Request | Payload | RIC | Async | Ethernet | No |
| Payload File Transfer Request | Payload | RIC | Async | Ethernet | No |
| Payload File Transfer Data Block | Payload | RIC | Async | Ethernet | No |
| <u>RIC to Ethernet Payload</u> | | | | | |
| Ancillary Data Set | RIC | Payload | Async, 0.1Hz, 1Hz | Ethernet | No |
| Broadcast Ancillary Data Packet | RIC | Payload | 10Hz | Ethernet | No |
| Rack Request response | RIC | Payload | Async | Ethernet | No |
| Rack Time Response | RIC | Payload | Async | Ethernet | Yes |
| EMU File Transfer Request | RIC | Payload | Async | Ethernet | No |
| Payload File Transfer Request | RIC | Payload | Async | Ethernet | No |
| Payload File Transfer Data Block | RIC | Payload | Async | Ethernet | No |
| Routed PEP Commands | RIC | Payload | Async | Ethernet | No |

C&D I/F's: HRDL Data packets

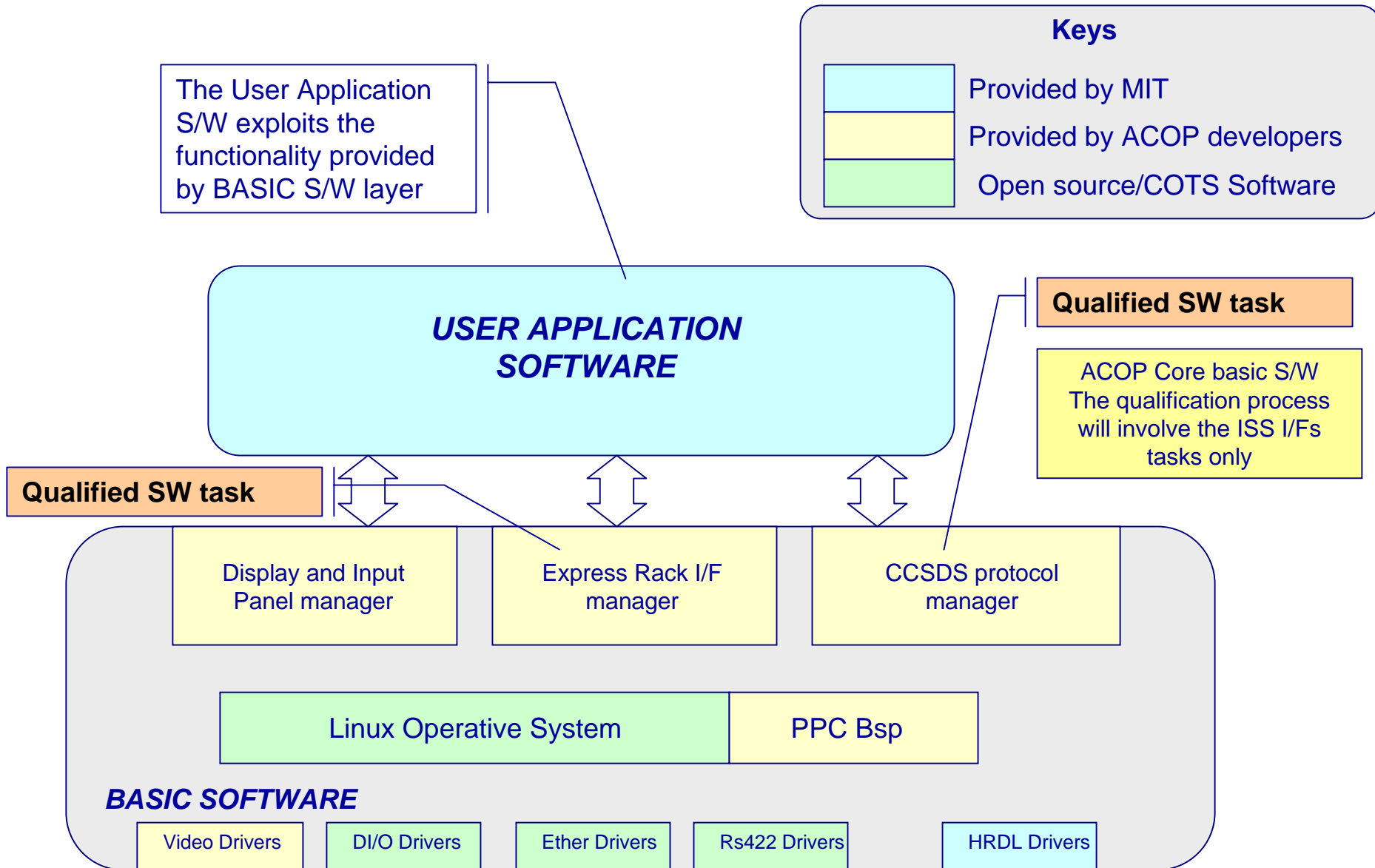
- On the Rs422 ACOP-RIC Interface are available the same data packets on Ethernet but for ACOP baseline the packets implementation is not foreseen.
- HRDL available data packets ACOP-AMS-02 (TBC)

| Description | Source | Destination | Frequency | Data Format | Utilization |
|-----------------------|---------------|--------------------|------------------|--------------------|--------------------|
| ACOP to AMS-02 | | | | | |
| ACOP Commands | ACOP | AMS | Async | HRDL | Yes |
| File Transfer Upload | ACOP | AMS | Async | HRDL | Yes |
| | | | | | |
| AMS-02 to ACOP | | | | | |
| Command Response | AMS | ACOP | Async | HRDL | Yes |
| AMS Health & Status | AMS | ACOP | Async | HRDL | Yes |
| AMS Scientific Data | AMS | ACOP | 20Mbps (peak) | HRDL | Yes |
| AMS House Keeping | AMS | ACOP | Async | HRDL | Yes |

SW Breakdown

- ACOP SW Breakdown
 - ACOP CORE S/W
 - ACOP CORE BASIC S/W
 - ACOP CORE USER APPLICATION S/W developed by MIT
 - ERLS (Express Rack Laptop Software) S/W
 - ERLS BASIC S/W
 - ERLS USER APPLICATION S/W developed by MIT

Software Top Level Architecture



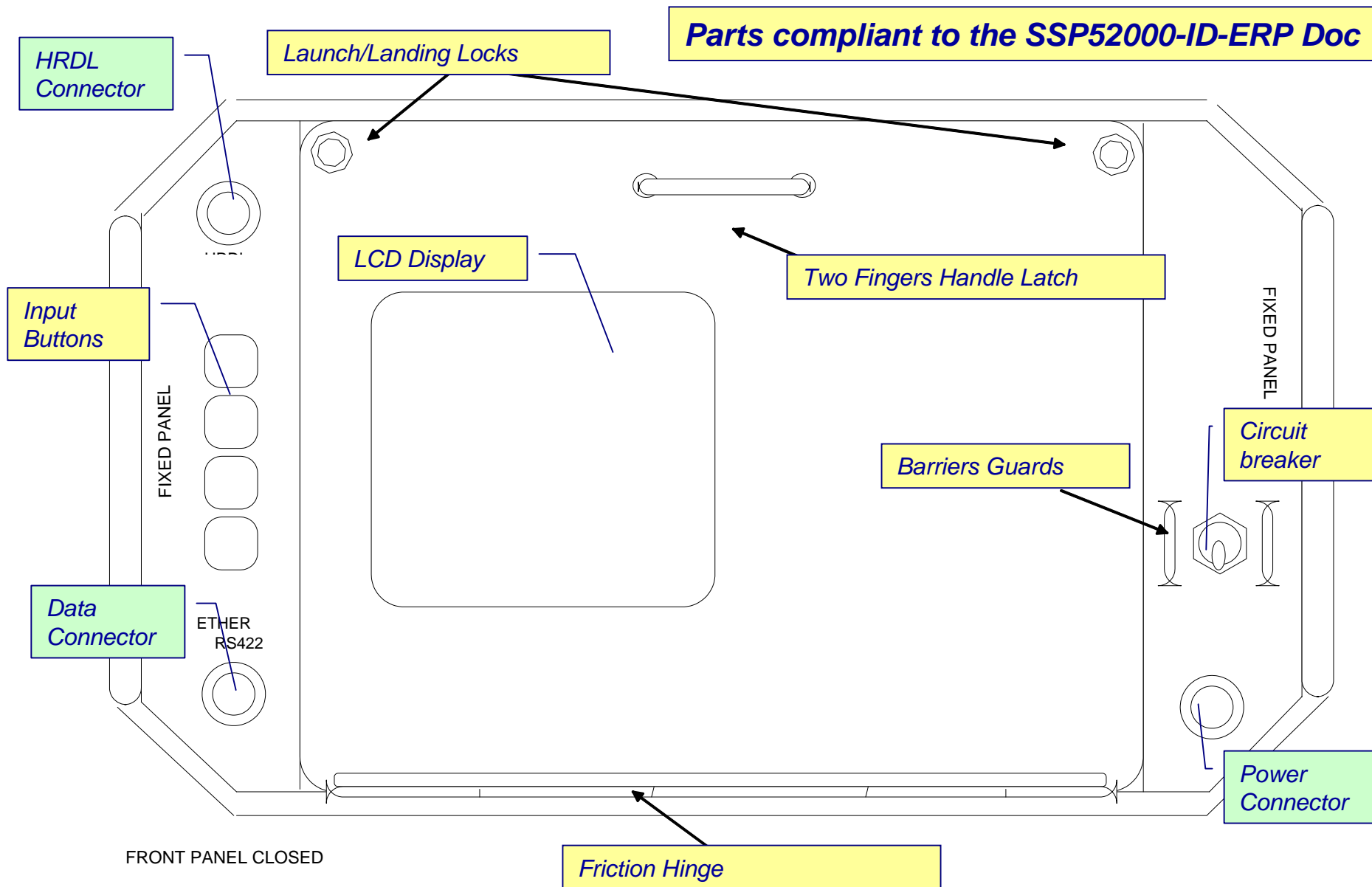
Safety

- ACOP will meet all safety requirements per SSP52000-IDD-ERP.
- Safety data packages will be developed for at least:
 - Fracture control
 - LCD panel. If required a guard cover will be used.
 - Rotating equipment
 - Hard drives (<8000 RPM)
 - Fans
 - Stored Energy
 - Batteries (CPU clock battery will be meet requirements or be removed)
 - Touch Temps
 - Front panel and interior access will have no hot spots
 - Sharp edges
 - Front panel and interior access will be inspected for sharp edges
 - Materials
 - Bills of material will be compiled and checked to comply with appropriate requirements.

Human Factor Interface

- The Human factor interface will meet the SSP52000-IDD-ERP document section 12.
- This requirement are applicable for the front panel and internal parts of ACOP to be replaced (ORU parts) or tool to be provided in order to replace the ORU parts.

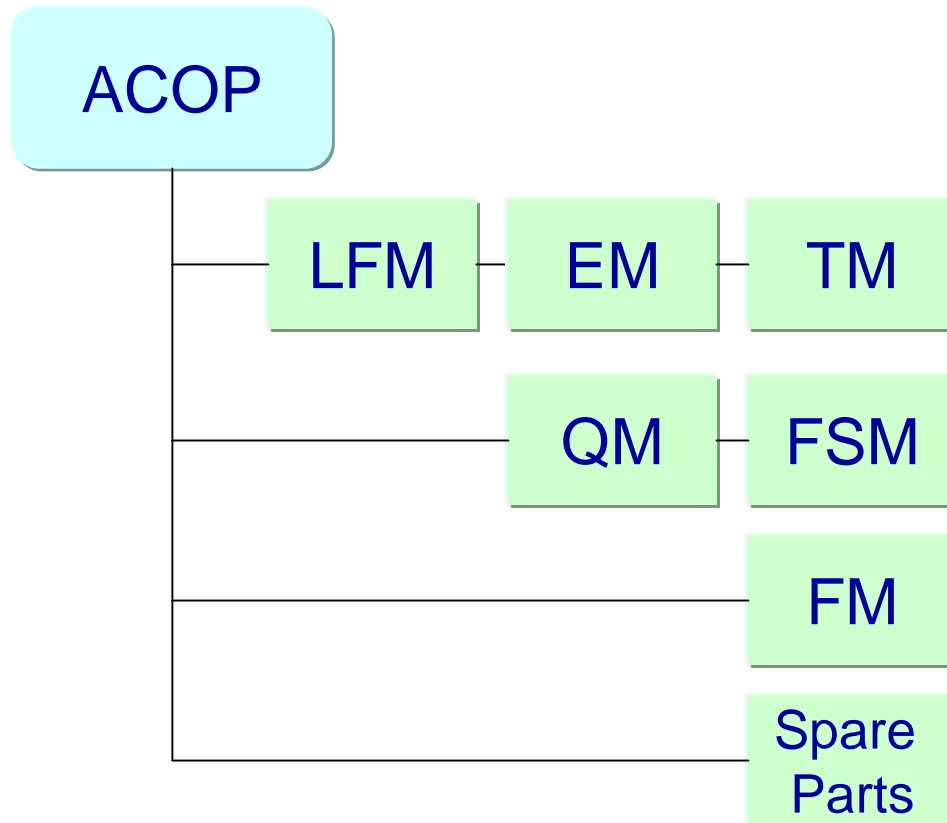
Front Panel Design



Acoustic Noise Requirements

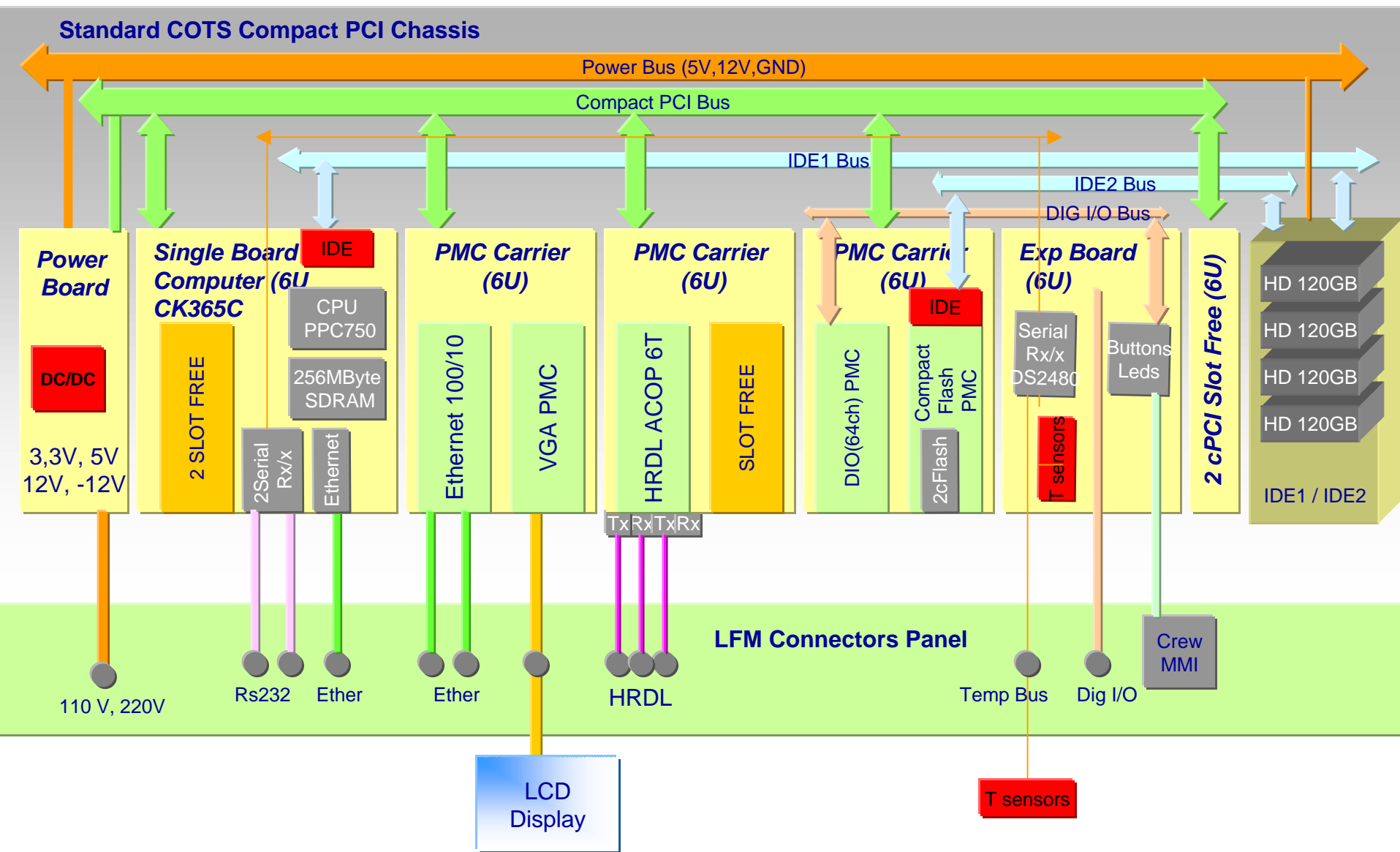
- The Total Sound Pressure Level (SPL) of the Integrated EXPRESS Rack (from all noise sources) will not exceed NC-40 (noise curve is shown in the IDD document) in any octave band between 63 Hz and 8000Hz when measured at the loudest location 60 cm inboard in front of the payload rack. (SSP52000-IDD-ERP section 4.7.2)
- ACOP is a “continuous noise source”
- Acoustic Noise limits
 - The acoustic limits that EXPRESS Rack payload shall comply are provided in the IDD doc Table 4-IX (continuous noise). These limits apply to measurement taken at the loudest location 0.6 m from each payload face (front, rear, top, bottom, left, right)
- To study ACOP’s compliance we need the noise curve for rack into which ACOP integrates.

ACOP Models

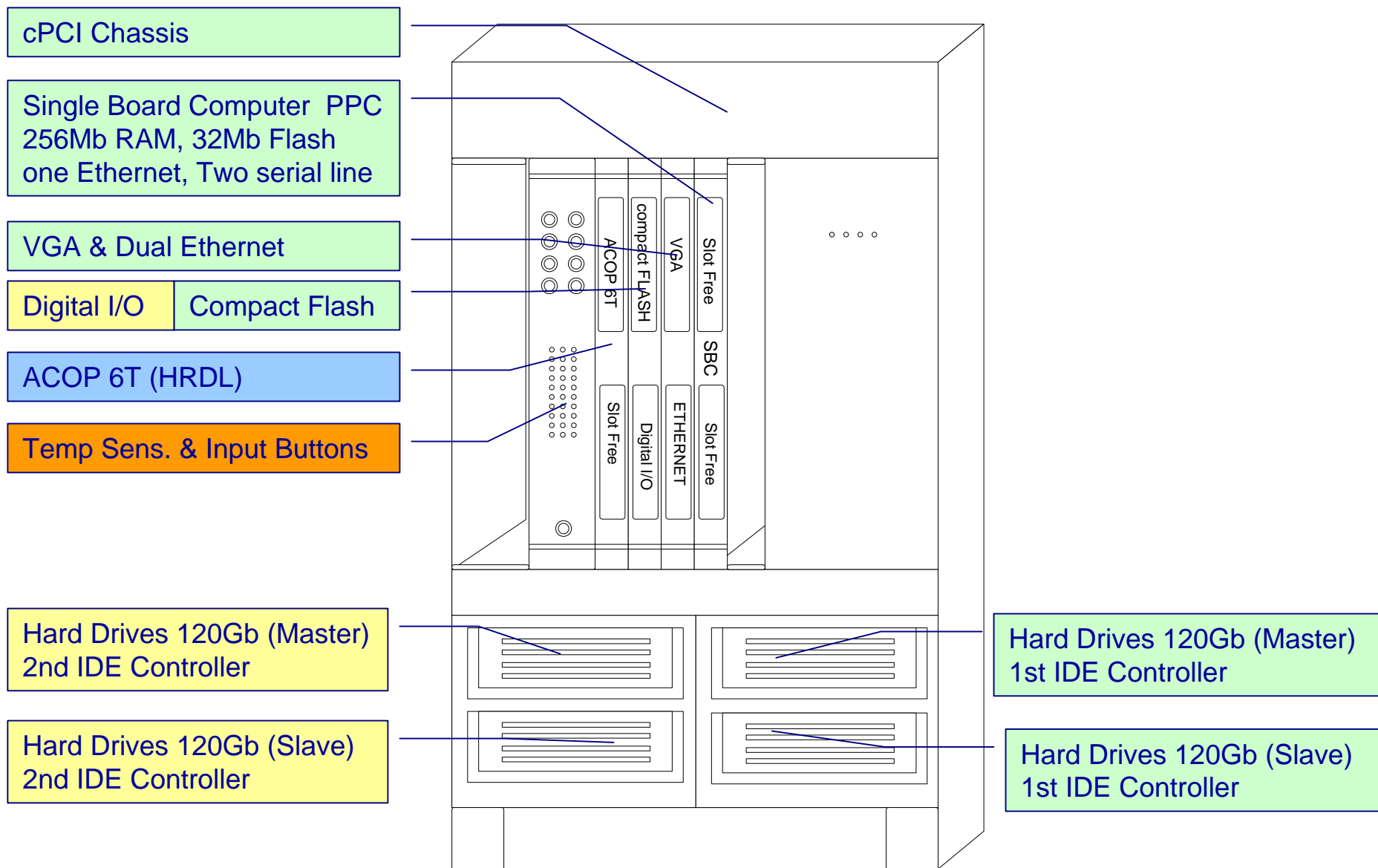


- LFM Low Fidelity Model
- EM Engineering Model
- TM Training Model
- QM Qualification Model
- FM Flight Model
- Flight Spare Model
- Spare Parts and ORU

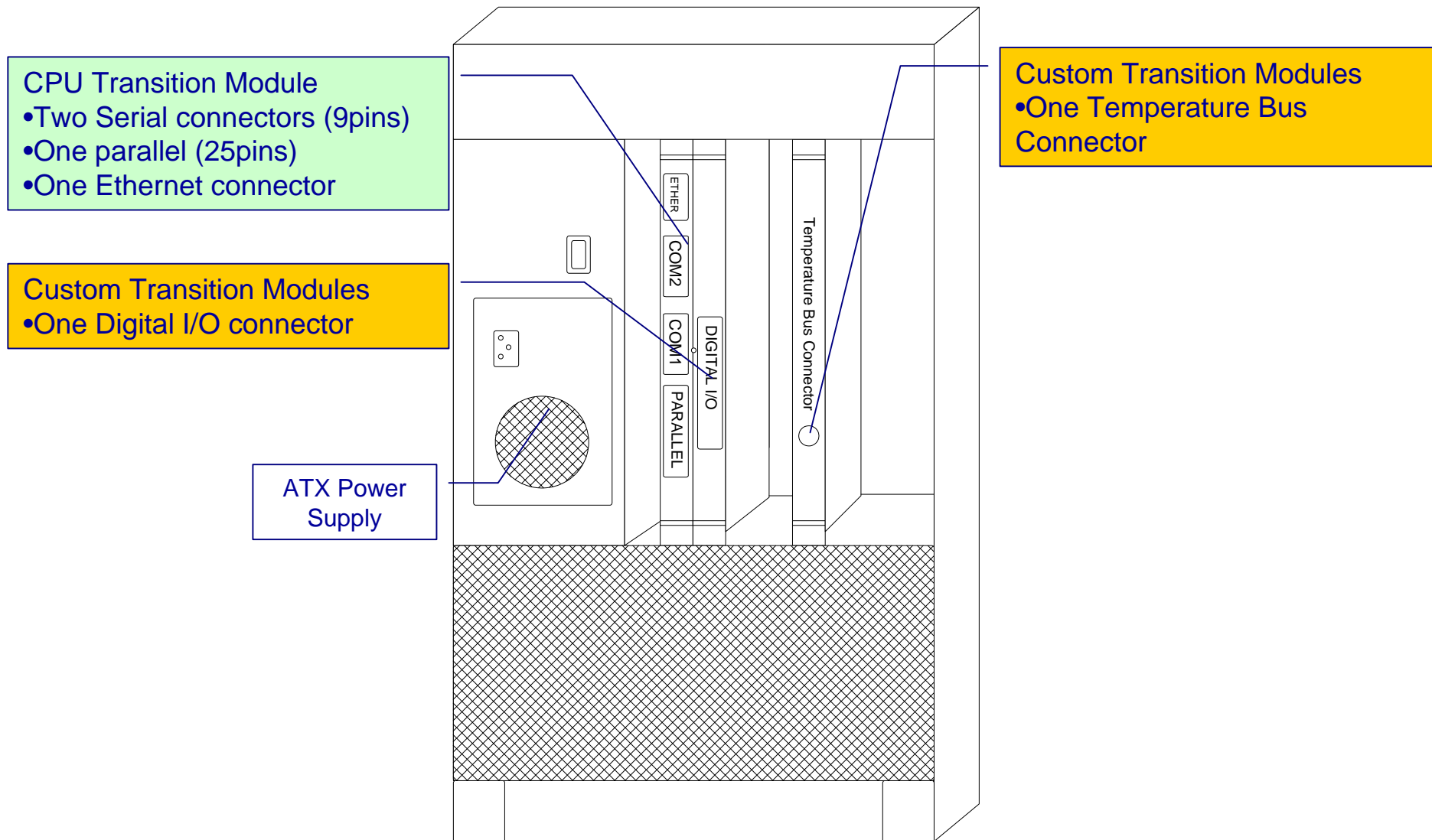
ACOP: LFM Architecture



ACOP:LFM front view



ACOP: LFM layout back view



ACOP/LFM

